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No

EG—Reading File

MSC-IN-65-EG-45

PROJECT APOLLO

FEASIBILITY OF FLIGHT TESTING LEM ABORT LAUNCH GUIDANCE SYSTEM IN EARTH ORBIT

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HOUSTON, TEXAS

October 29, 1965

SUMMARY

A method of testing the abort launch guidance system of the Lunar Excursion Module in earth orbit is described herein. This method consists of the onboard computer issuing ascent thrust commands based on the vehicle state relative to a ficticious moon while the LEM propulsion system actually executes the commanded thrust profile in a near earth orbit. Results of a digital simulation indicate that the concept is feasible.

INTRODUCTION

To flight test the Lunar Excursion Module propulsion system, an unmanned mission in earth orbit has been proposed in reference 1. The design of this mission has been restricted by such constraints as location of the vehicle relative to the tracking stations at the time of thrust and longevity of the final orbit at the end of all thrusting maneuvers. If the thrusting maneuvers were commanded by the onboard computer, it could be tested along with the propulsion system. Generally, this report indicates that the guidance computer can be included in the test compatibly with propulsion system and the operational constraints. Specifically, the feasibility of flight testing the lunar ascent guidance in earth orbit is shown herein.

STATEMENT OF THE PROBLEM

The problem geometry is illustrated in figure 1 where part a represents the computer world (referenced to the ficticious moon) and part b represents the real world (referenced to the earth). The LEM is depicted nearing completion of the ascent burn test. In order to assure maximum data reception by the ground tracking stations during an earth orbit test of the LEM propulsion system, the mission described in reference 1 was carefully constrained such that all thrusting maneuvers occur well within ground tracking capability. This included limiting altitude to a maximum of 300 nautical miles. Also, the expected lifetime of the final orbit was restricted to not exceed three months to prevent a potential collision with another spacecraft. Adherence to these criteria must be observed when designing a test mission which includes the guidance computer as a part of the system to be tested. Thus, the ascent guidance equations and logic may be tested intact if the ascent thrusting maneuver can be fitted into the test mission without violating the mission ground rules.

DIGITAL SIMULATION

The digital simulation used in this feasibility analysis consists of two mathematical flow loops: one represents the guidance computer onboard the LEM; the other simulates the realworld earth orbit. A flow chart of this simulation appears in figure 2. Nominal lunar launch conditions are input to the guidance computer which seeks the 50,000 ft. altitude circular orbit end conditions by use of MIT ascent guidance (fig. 3). The LEM --

ficticious moon relative state which is used by the guidance as a basis for the thrust commands is updated by average g equations with the sensed acceleration. In the earth orbit loop the state vector is updated by a Runge-Kutta 4th order integration of the actual acceleration.

ANALYSIS

To execute this analysis a 100 n.mi. altitude circular earth orbit was assumed prior to the LEM ascent stage thrusting maneuver. A sequence of runs was made varying the initial attitude of the LEM. In this way the effect of the ΔV due to thrust upon the orbit was also varied. Point mass gravitation and Keplerian orbits were assumed. The runs were continued until an initial vehicle orientation was found that yielded (after the thrusting maneuver) an orbit similar to the resultant orbit of reference 1. These orbital data are tabulated in fig. 4.

RESULTS AND DISCUSSION

The initial conditions of the LEM which yielded a promising orbit after the nominal lunar launch thrusting maneuver are tabulated in figure 5. Time histories of the LEM characteristics, altitude, pitch, and yaw during the 400 second thrusting period are presented in figures 6 through 9 for both the real world and computer world situations. Using MIT ascent guidance, the computer world nominal launch from 816 ft. to 50,000 ft. is shown in figure 6 and pitch and yaw are presented in figure 7. The vehicle pitches from 33.5 to -4.2° while the yaw angle remains at a constant 90°.

The time history of real world altitude is shown in figure 8. The thrusting is initiated at 100 n.mi. and it is evident that the maximum altitude of 113.35 n.mi. is well within the limiting criteria of 300 n.mi. for tracking during thrust. A history of real world pitch and yaw is presented in figure 9. The pitch profile ranges from 6° to -19° and yaw from 73° to 109°.

It should be noted that in this case there is a 7° plane change as compared to a .2° plane change in the mission described in reference 1 which must be taken into consideration when planning the tracking.

If the telemetered data from the onboard computer indicate a successful maneuver, it can be assumed that any deviation from the predicted real world altitude, pitch, or yaw is due to errors in the hardware. The entire thrust maneuver (400 sec.) can be executed over continental United States, thus providing adequate ground control and tracking.

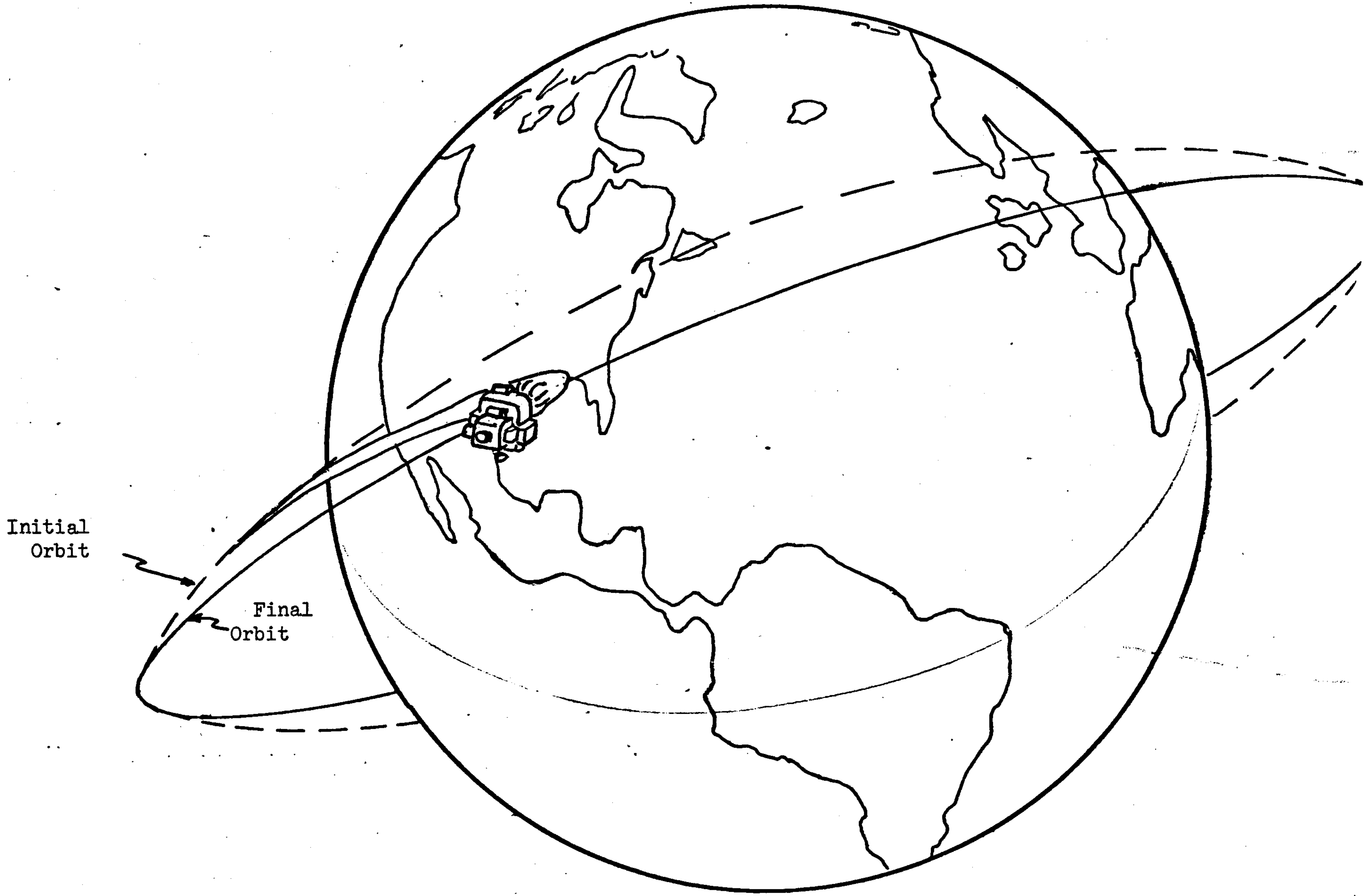
CONCLUDING REMARKS

A feasibility study of including the LEM ascent guidance in the propulsion system test in earth orbit has been made and is reported herein. It has been shown that with the proper initial attitude the LEM can execute the nominal lunar ascent maneuver while in an earth orbit. Thus, the ascent guidance could be used to command the test thrusting maneuver based on a ficticious moon.

REFERENCES

1. Apollo Mission SA-206A Spacecraft Preliminary Reference Trajectory (U). TRW Systems Document 3300-H007-RC0000, July 1, 1965.

Figure 1.- Problem Geometry, Lunar Ascent Trajectory
a. Computer World



1(b) Real world

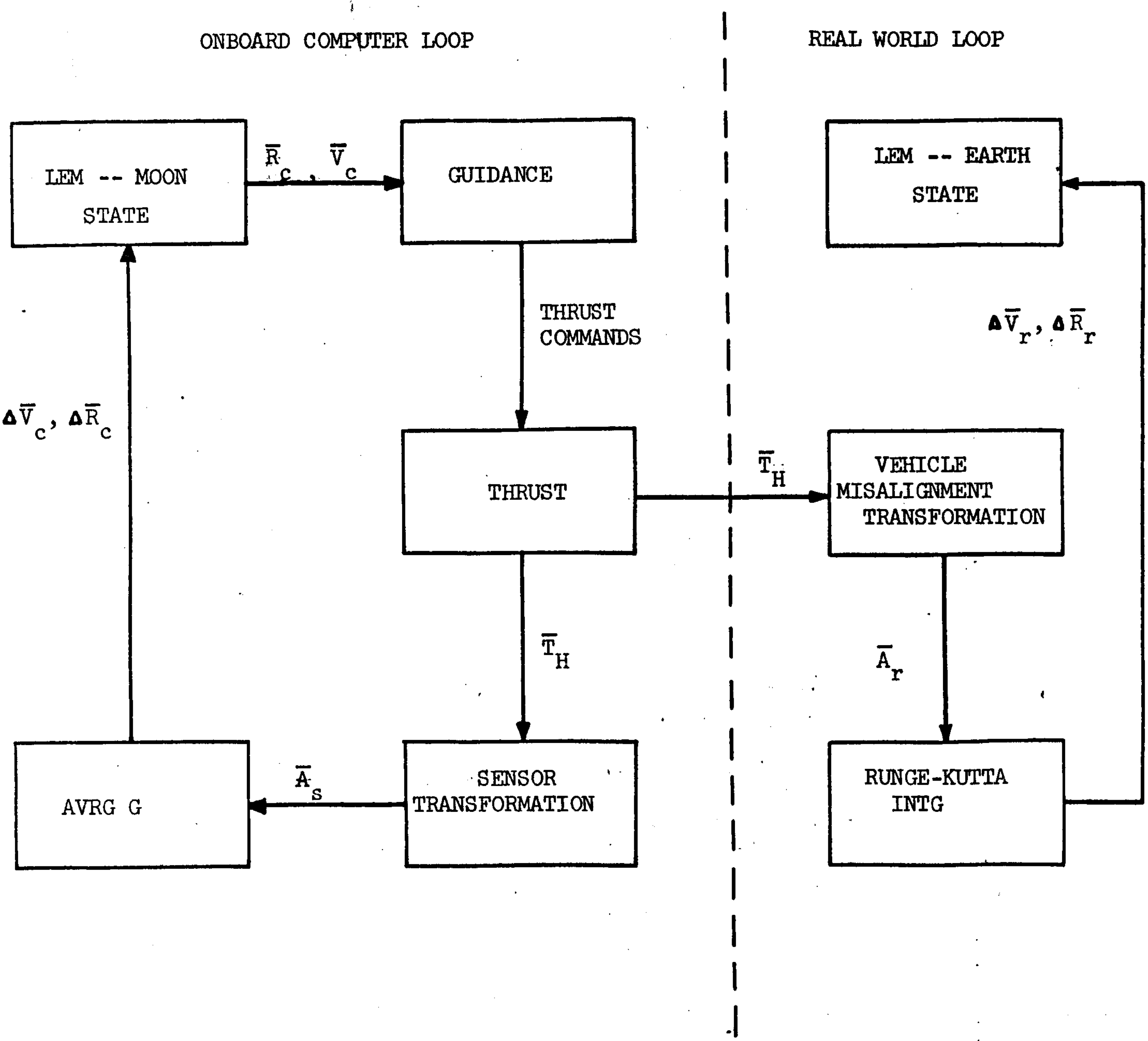


FIGURE 2 DIGITAL SIMULATION FLOW LOOPS

	ALTITUDE (ft)	VELOCITY (FPS)	GAMMA (°)	AZIMUTH (°)	LONGITUDE (°)	LATITUDE (°)
INITIAL CONDITIONS	816.4	88.3	83.1	90.	0.	0.
FINAL CONDITIONS	50,000	5483.	0.	90.	9.56	0.

FIGURE 3 NOMINAL LUNAR LAUNCH DATA

	PERIGEE (n.mi)	APOGEE (n.mi)	INCLINATION (°)
ORBIT BEFORE PROPOSED ASCENT PROPULSION SYSTEM TEST *	140.9	223.7	31.425
ORBIT AFTER PROPOSED ASCENT PROPULSION SYSTEM TEST *	109.7	284.8	31.236
ORBIT BEFORE ASCENT GUIDANCE SIMULATION	100	100	30**
ORBIT AFTER ASCENT GUIDANCE SIMULATION	113.8	280.2	37.1**

*Proposed in Reference 1
**Independent quantity; relative value of significance

FIGURE 4 ORBITAL DATA COMPARISON

Pitch From Local Horizontal	Yaw From Orbital Plane	Altitude	Speed	Inclination & True Anomaly
5.93°	73.42°	100 N.MI.	25,567 FPS	Free to be chosen by the Mission Planners

Figure 5.- Initial Conditions in Earth Orbit

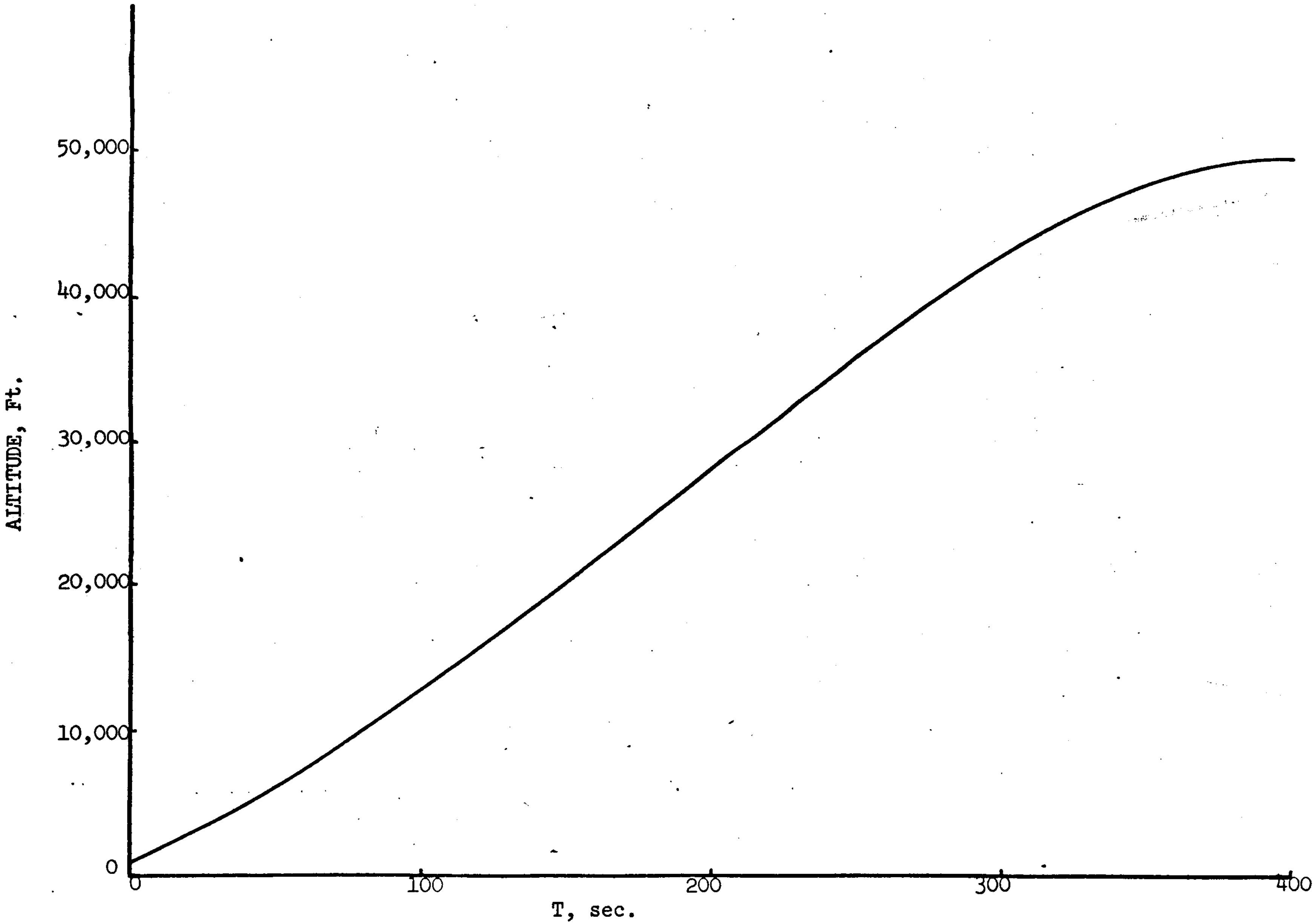


Figure 6. Time history of computer world altitude during thrust.

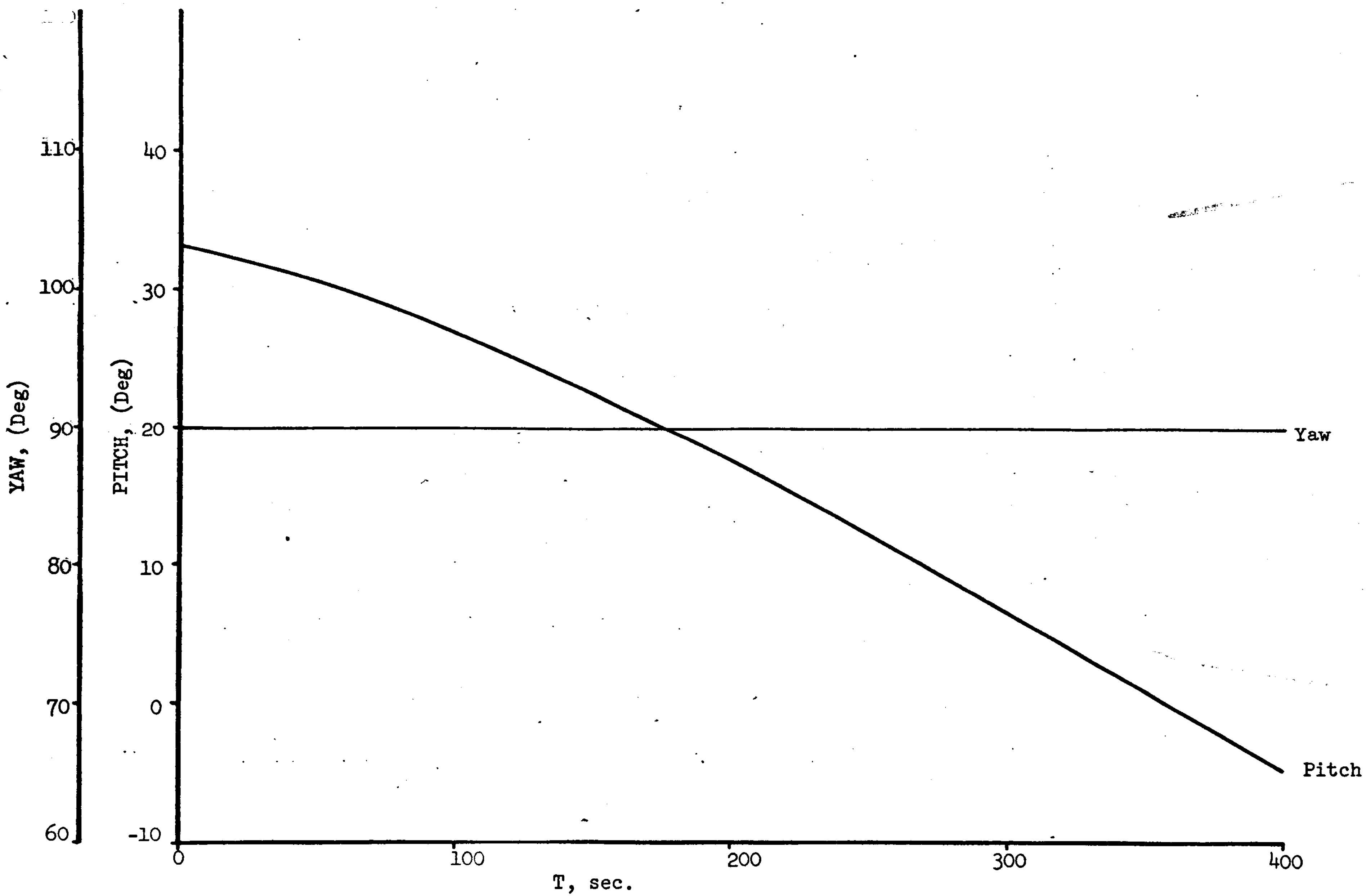


Figure 7. Time history of computer world attitude during thrust

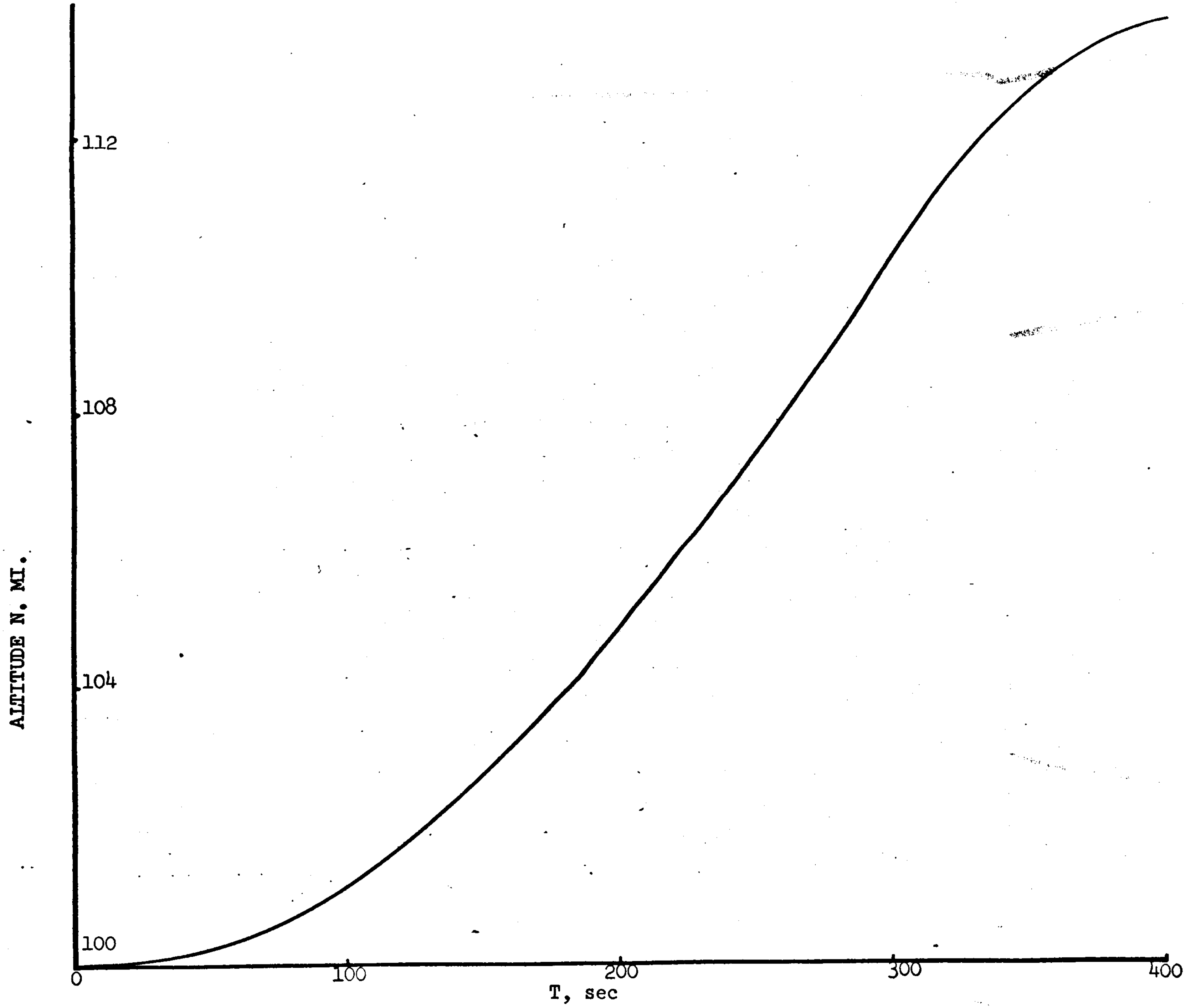


FIGURE 8. TIME HISTORY OF REAL WORLD ALTITUDE DURING THRUST

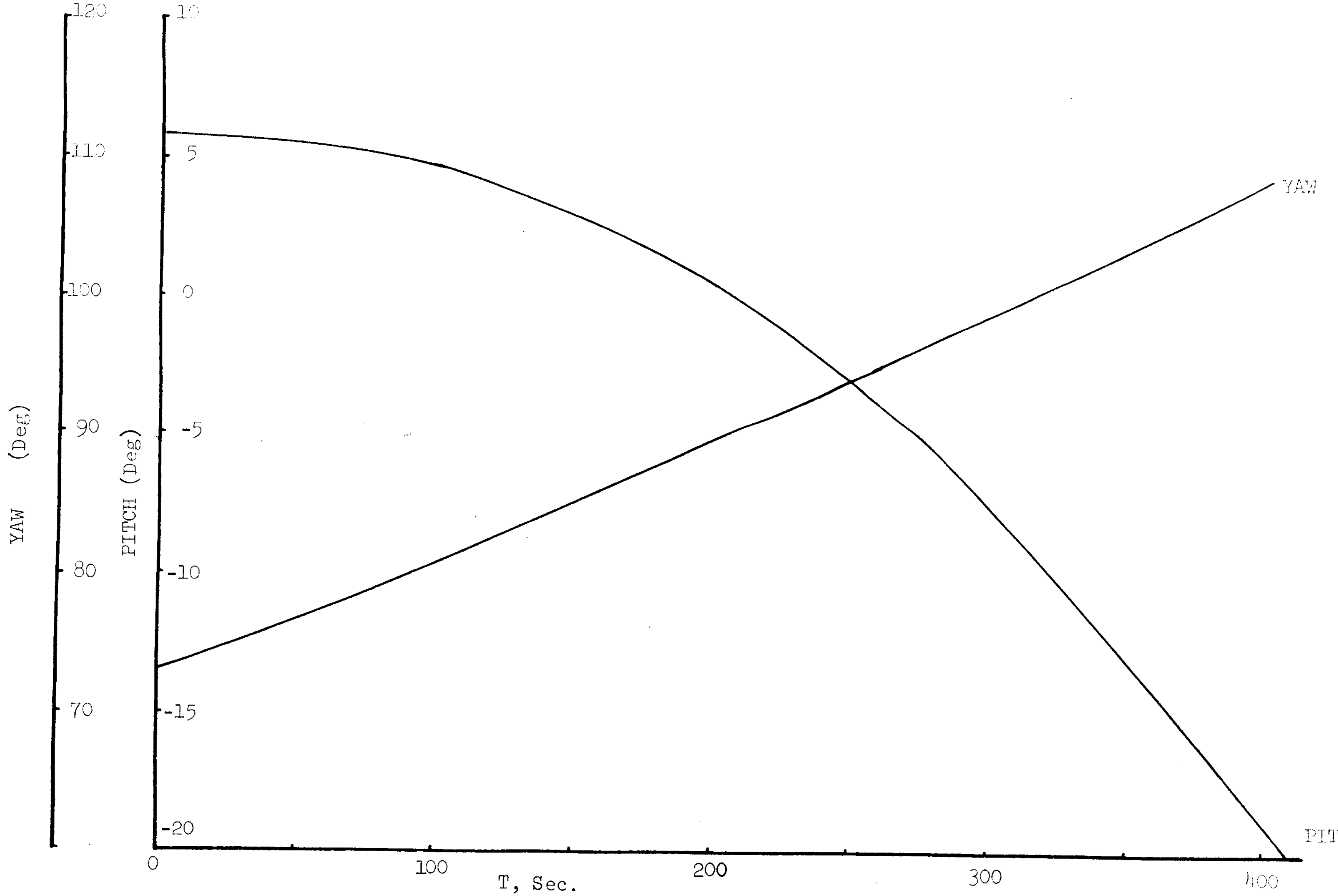


FIGURE 9 TIME HISTORY OF REAL WORLD ALTITUDE DURING THRUST